

A Brief Summary of a Four Week Interaction
with Dr. Christian Soize and his Colleagues
at ONERA in Chatillon, France

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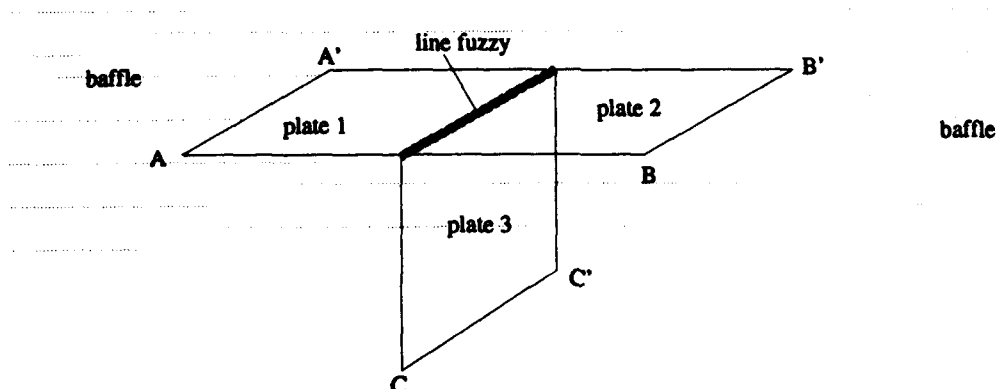
Executive Summary

During the four week time period 9 June to 14 July 1993, the author visited ONERA (Office National d'Etudes et de Recherches Aérospatiales) in Chatillon, France and interacted with the scientists and engineers in their structures group. The primary purpose of the visit was for the author to work with Dr. Christian Soize, on one (or more) of three problems suggested in discussions between Soize, Dr. Victor W. Sparrow, and Russell at the Fall 1992 meeting of the Acoustical Society of America in New Orleans and in subsequent correspondence. Other objectives included understanding more about Soize's fuzzy structure theories, learning (if possible) about some of the finite element computer code used by ONERA, observing the kinds and quality of research being done by the structures group, and laying some ground work for possible future interactions between French and American scientists concerning fuzzy structures. Many of these objectives were met. One major result of the visit was the development of a model for coupling between a line structural fuzzy and the bending motion of attached plates.

Fuzzy Structure Problems

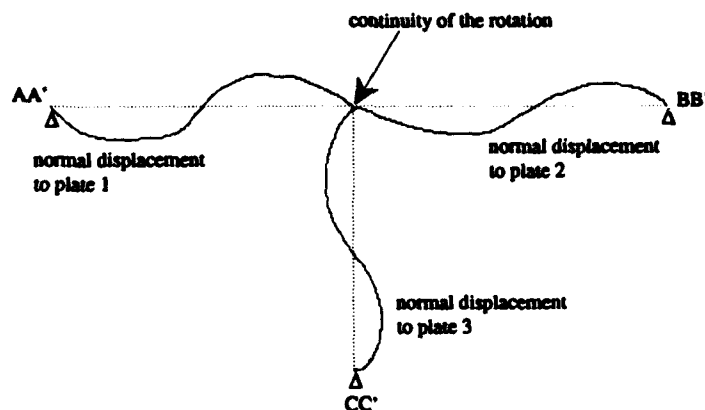
The proposed problems which had been discussed between Soize, Sparrow, and Russell at the New Orleans ASA meeting are shown and described below.

1: scattering from a baffled plate with attached continuous line fuzzy.

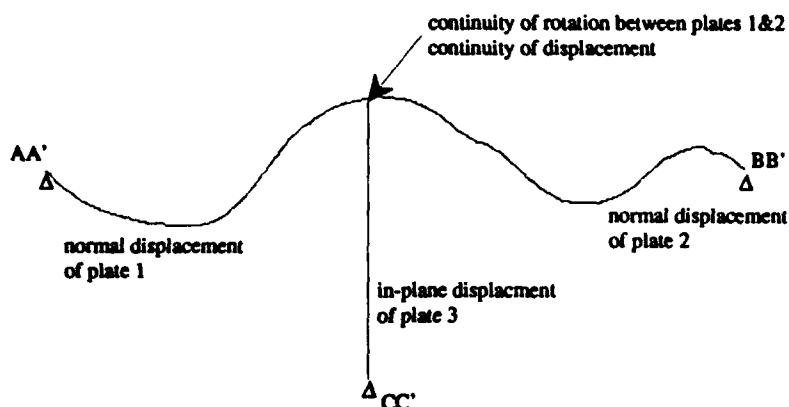


This problem may be broken into two subcases

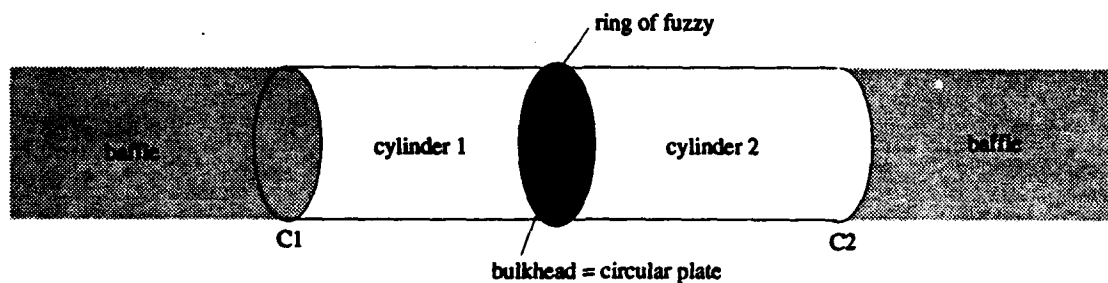
1a: All three plates are simply supported and move only in bending modes, the eigenmodes being known. On the line fuzzy, the normal displacements of plates 1 and 2 is zero and the coupling between plates 1, 2, and 3 is made by the rotation around the line fuzzy.



- 1b: Plates 1 and 2 move only in bending mode and plate 3 moves only in a membrane mode. The normal displacement of plates 1 and 2 on the line fuzzy is not zero and there is continuity of this normal displacement on the line fuzzy and continuity of the rotation around the line fuzzy for plates 1 and 2, assuming no bending in plate 3. The eigenmodes of each plate are not explicitly known.



- 2: Scattering from a finite cylinder with continuous ring fuzzy. The cylinders are simply supported in an infinite baffle. The circular plate bulkhead is simply supported and moves only in a bending mode. The eigenmodes of each finite cylinder and bulkhead are known. The point of contact of the ring fuzzy may be treated as two subcases in a similar fashion to problem 1.



Four Week Project

Upon my arrival at ONERA, Dr. Soize and I discussed in more detail the three problems proposed at the New Orleans ASA meeting, and specifically what we might be able to accomplish in four weeks. Initially Soize and I decided to pursue a numerical study of problem 2, the cylinder and ring fuzzy. Apparently their finite element code is more easily adapted to baffled cylinder problems than to baffled plates. Annick Desanti is the engineer in the structures group who writes/modifies the finite element code and controls most of the big jobs that are run on the CRAY. She and Soize and I considered the parameters needed to solve the cylinder problem for physical, finite element, and mid-frequency analysis. However, after several hours of consideration it was decided that the cylinder problem would not be appropriate for my four week project. Computer run time on the CRAY would have amounted to approximately 100 hours, which was more expensive than they felt they could afford for my visit. In addition, the complexity of the finite element code would have required that ONERA engineers do most of the coding since it would have taken me too long to become familiar with it, and if a satisfactory solution was not obtained within four weeks then I would have had nothing to bring back to Penn State to continue working with here.

So, Soize and I decided to begin an analytical study of problem 1a with the line fuzzy and plates in bending mode only, carrying the analysis as far as possible in four weeks, with the understanding that I would continue working on the problem with Sparrow upon returning to Penn State. Since the coupling between the plates 1, 2, and 3 comes through the rotation about their junction we decided to first investigate the rotational behavior of plate 3 and use these results to model the line fuzzy. One of Soize's specialties is the response of structures to random excitation, and he suggested that a random bending moment be applied to the edge of plate three corresponding to the junction. The resulting rotational behavior plate 3 could then be determined. Soize suggested modeling the line fuzzy at first with a type 1 fuzzy law which does not consider spatial memory, using the rotational behavior of plate 3 to model the mean values of the fuzzy parameters. The fuzzy mass was the only parameter which could not easily be determined, so Soize devised a mathematical technique for obtaining an approximation of the fuzzy mass by minimizing

the difference between the rotational behavior of plate 3 and the rotational behavior of the line fuzzy.

During the remaining three weeks of my visit, I spent most of my time completing the mathematical details of this minimizing technique and developing some FORTRAN code to implement it. Unfortunately I was not able to work all the bugs out of my code and so did not get any final results before I left ONERA. I am continuing to work on the problem at Penn State and will be in communication with Soize concerning the results I obtain and future steps for continuing study of this problem. A detailed mathematical report of the problem and my results so far may be obtained upon request.

After the mean fuzzy parameters have been determined, and suitable dispersion limits have been set, the coupling between the rotation of the line fuzzy and the bending motion of plates 1 and 2 may be investigated. Subsequently, scattering results may be obtained. Soize also suggested that once results have been obtained using a type 1 fuzzy law, the same method could be used with a type 2 fuzzy law taking into account some spatial memory along the fuzzy attachment.

Status of Soize's Fuzzy Research

With the exception of the four weeks I spent working with Soize, there is no current active research in the area of fuzzy structures going on at ONERA. Most of the work on fuzzy theory as well as most of the foundational work on the mid-frequency method was done in the early to mid 80's. A vast majority of the work on fuzzy theory has not been published in international journals, though there is quite a large amount of documentation in the form of internal ONERA reports. Some of these are classified. During the last couple of years, Soize's fuzzy research has focused around the development of the type 2 fuzzy law which accounts for spatial memory. He presented the basic outline and some results of the type 2 law at the Fall 1992 ASA meeting in New Orleans, and which appeared in JASA in August 1993. However, there is no current work being done on fuzzy theory, with no funding and no graduate students working on problems dealing with fuzzy structures.

Soize and his colleagues seem very confident that they understand and have developed the fuzzy theory enough to apply it to prototype submarines. As I expected, I was not able to get information about any comparisons of experimental results to computational results obtained using fuzzy theory. Soize admitted that because of funding and time limitations, while they did apply the fuzzy theory to large, complicated structures like submarines, they were not able to apply the fuzzy theory to simple structures like those that Dr. Sparrow and I are working with. He is very interested in the problems that Dr. Sparrow is investigating and thinks that such research, applying fuzzy theory to simple problems involving plates and shells, is very important. He was very enthusiastic about the problem he proposed for me.

I think that Dr. Soize is very interested in continuing to collaborate with Dr. Sparrow and I about the fundamental problems that we are working on. He stated that he felt the problem he proposed for me was a good program for a Ph.D. thesis. He expressed a desire to be informed of any progress that I made and told me to contact him with any problems or questions that I had about the problem or about his fuzzy laws. I think that if money and time were available to him that he would continue research on fuzzy structures.

One thing that I did not see while at ONERA was a correlation between numerical results and experimental data. Soize's published results and the unclassified results that I

saw showed comparisons of computed results using fuzzy theory agreeing well with numerical results obtained with Monte Carlo techniques, but I did not see any comparisons with measured results from actual physical structures. Perhaps, because of time and funding limitations, none have been performed except for classified experiments concerning the submarine prototype. This could be an area where we in the U.S. could fill in the gap. We could study some of the more simple but fundamental problems that so far have not been addressed, and provide comparisons between theoretical/numerical applications of the fuzzy theory and measured results obtained from equivalent physical structures.

ONERA

Almost all of the research that goes on at ONERA deals with aerospace; studies of vibration of aircraft, noise and vibration control of aircraft, airflow around parts of and whole aircraft, studies of French spacecraft including their development of a reusable shuttle. A considerable amount of research is done for Airbus in addition to military applications. There are three main ONERA locations; Chatillon, just outside of Paris, Toulon in the south of France, and one other location. The research division at Chatillon is located in a very simple looking building, about 15 stories tall, on a hill in a quiet suburban area. The Chatillon division seemed to be mostly offices, where scientists and engineers conduct theoretical research, as well as computer simulation, finite element analysis, etc.. I did not see evidence of any large experimental laboratories at Chatillon. I did see a video presentation summarizing some aspects of ONERA research which showed large wind tunnels, large labs big enough for studying airplane wings and turbine engines, but these experimental facilities are probably at the other locations.

The structures group occupied offices in a small hallway at one end of the second floor of the main building at Chatillon. I was not given a tour of the entire facility so I do not know what the rest of the building contained. Every morning I traded my passport for a visitor's pass and had to be escorted into the building by someone from the structures group. Once inside I was free to go to the cafeteria alone if I so desired, but I did not wander around the rest of the building, so I am not sure how strongly security is enforced. My briefcase was never checked upon my leaving at the end of the day.

Personnel in the Structures Group

There are about 20-25 people in the structures group. Below is a list of the people belonging to the structures group with whom I interacted. It is not a complete listing as there were some people who I did not meet or work with. Neither are their job descriptions complete, as I did not get a chance to discuss research with each of them.

- Christian Soize is the Deputy Head of the Structures Division. I interacted with Dr. Soize more than with anyone else in the group, but then that is why I went. He proposed the problems I worked on, developed the mathematical method, answered my questions, and checked my progress. Soize is a very friendly person and was very easy to work with. His grasp of his subject material impressed me greatly. He is full of energy and seemed to be actively pursuing research on several problems simultaneously with other group members, as well as finishing the writing of a new book, writing papers, and preparing viewgraphs for upcoming meetings. I consider myself very lucky to have had the chance to interact with him.
- Annick Desanti seemed to work primarily as a computer programmer, writing and running FORTRAN code on the CRAY system, working with the finite element codes, ADINA and NASTRAN, and modifying them to incorporate the mid-frequency method and fuzzy theory. Had the problem Soize outlined for me been more computational oriented, I would have interacted much more with Mlle. Desanti.
- Mr. Grisvald is the group head. On my first day he gave me a brief overview of the structures group, some of the research problems they are investigating, and introduced me to everyone. I approached him with any administrative type problems I had if Soize was not available.
- Alan Dugeai, among other things, managed the computer system. He set up my account on their Apollo workstation network, introduced me to their system, and helped me with all of my computer related questions or problems.
- Jean Michel David is the group expert on structures. I saw him spend a considerable amount of time developing finite element meshes for complex structures analyzed by the structures group and other groups.

- Paul Soudais does theoretical and computational work applying the finite element analysis and mid-frequency method to electromagnetic problems. He will be spending a year at the University of Illinois at Chicago beginning this fall.
- Benoit Petitjean works primarily with active and passive noise and vibration control. He spent the 1992-93 academic year at an American university.
- Olivier Voisin-Grall is the newest engineer in the group, joining them a year ago. His primary job is to study the newly acquired finite element software NASTRAN and compare it to the ADINA code currently in use.

In addition there were at least seven other engineers/scientists working on various aspects of finite element analysis, or theoretical analysis of structures, at least two graduate students who were doing their Ph.D. research at ONERA, two young men fulfilling their military/civic duties by working at ONERA for a year, and two other students who were satisfying a three month training requirements for their schools by working at ONERA.

Computer Facilities

1. Hardware

The primary computers used by the structures group are Apollo 2500, 3000, and 3500 workstations. These are networked together with each other and with an Apollo 10000 which serves as the main number crunching machine for problems not requiring the use of a CRAY. There are also two HP 7900 workstations connected to the Apollo network with two more HP's to be arriving this fall. During the four weeks I spent at ONERA, I saw the HP workstations being primarily used for mesh generation using I-DEAS, text processing with T_EX, or other problems requiring graphics. The Apollo workstations were being used for text editing, FORTRAN programming, and for plotting graphs. The FORTRAN compiler on the Apollos is the Apollo Domain Fortran compiler. This compiler does not conform exactly to FORTRAN 77, but has additional commands and functions, and syntax.

In the acoustics department at Penn State I primarily use a HP 9000 to run FORTRAN and C programs, and to make 2-D plots, and a NeXTstation Turbo for running *Mathematica* problems and for processing text documents with T_EX. These workstations are fairly fast and I became somewhat frustrated with the slowness of the computer facilities of the structures group at ONERA. The smaller Apollo workstations were very slow. Simple things like logging in, or opening up a new window on the screen to edit a file took several seconds. Compiling a small, simple FORTRAN program took several minutes. The Apollo 10000 was much faster, though considerably slower than the HP 9000 of the acoustics program at Penn State. Some of the FORTRAN programs I wrote while at ONERA took several minutes to run on the Apollo 10000. The same programs ran in several seconds on the HP 9000 at Penn State.

Larger computational problems, especially those involving finite element analysis are run on a CRAY-YMP. I do not know who controls the CRAY or how computational time is allotted or run time charged. Annick Desanti and Benoit Petitjean were the people I saw interacting with the CRAY the most. In other offices outside of the structures group I saw several computers that looked like Sun workstations as well as quite a few MacIntoshes.

2. Software

At least since 1980, the primary finite element software used by the structures group is ADINA, with much modification and enhancement to enable the solving of problems studied by the structures group, especially for mid-frequency analysis and fuzzy structure theory. Since the project I was working on was largely theoretical, I did not have the opportunity to look at or use this software. The ONERA division at Toulon wants to switch to the finite element system NASTRAN. A couple of engineers at Chatillon were studying NASTRAN to see if it could be manipulated to perform the calculations that are possible with ADINA and the modifications they have made to it.

The primary graphics program used for plotting 2-D plots is a program called B.R.I.C.E. and was written by some computer graphics people at ONERA. It is menu driven (in French) and is similar to a graphing program like Delta Graph. The structures group does not use *Mathematica* though a few of them are familiar with it. They do have and use Maple, and are in the process of purchasing Mathcad/MatLab. With the exception of Mr. Petitjean, no one in the group uses E-mail. He has it only because he got used to having it while working in the U.S. for a year and wished to keep in touch with people.

General Impressions

My research experiences in the U.S. have been limited to the academic environment and two summer internships in private industry (EXXON). I have not yet visited a U.S. government research lab such as NASA, ONR, or NRL, so I cannot really make many general comparisons between what I saw at ONERA and what I have seen here. The building in which the Chatillon site of ONERA is housed is not an outwardly impressive building, but instead is very plain looking. The offices belonging to members of the structures group are very simple, and quite devoid of any personal decoration on walls or desks. Closed cabinets replace open book shelves; those that I saw the insides of contained mostly paper printouts and manuals. I was quite surprised at the lack of books. Natural lighting from windows seems to be preferred, and the fluorescent ceiling lights were seldom used while I was there. Computer screens were dimmed. Paper and office supplies were available, but did not seem to be in great abundance. Some offices that I saw in other parts of the building were decorated a little more, but most were pretty much the same. Perhaps this government laboratories in the U.S. have a similar atmosphere, but I was quite surprised. I am used to academic settings where books cover every bit of shelf space available, and pictures on walls and desks add a personal touch to an office.

The overall atmosphere in the structures group seemed to be pretty relaxed, and this also surprised me. There did not seem to be any rush to meet pressing deadlines, or to finish a project before an important briefing. With the exception of Dr. Soize, everyone that I saw seemed to be pretty laid back about whatever they were doing. Dr. Soize, in contrast, is a bundle of energy, always rushing here and there, thinking about several problems at once. The workday ran from about 8:30am to about 5:00pm except for Fridays when everyone leaves at 4:00pm. The French put in a 39 hour work week. These hours were not strictly adhered to, there were no time cards to punch, no supervisors checking to see that progress was being made. No-smoking policies have apparently been announced, but are not enforced. Dress was casual for most of the engineers, though Soize wore jacket and tie most days.

The experience for me was very rewarding. I am very grateful for having had the chance to work directly with Soize. I learned quite a lot, and am beginning to understand

his fuzzy theories much better than before. The problem we began to study should yield some interesting results, as well as providing a technique for analysing structures with continuous fuzzy attachments.